SECTION 230900 –INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Work Scope Summary

B. System Description

C. Related Sections

D. Description.

E. Approved Control System Contractor

F. Quality Assurance

G. System Performance

H. Submittals

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J. Ownership of Proprietary Material

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L. Testing and Balancing

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1.2 WORK SCOPE SUMMARY

A. Furnish all labor, materials, equipment, and service necessary for a complete and operating Building Automation system (BAS), utilizing Direct Digital Controls as field verified and as described herein. This includes replacing all actuators as needed for a properly controlled and operating sytem.

B. This project is an extension of the Owner’s Tridium Niagara AX control system. It is the owners desire to match the current level of graphics and navigational aids, to include the trending of all data points.

C. The existing BAS is a Johnson Controls Metasys digital control system. The existing Johnson Control supervisory N31 panel(s) must be replaced with a new Tridium JACE 600 or Honeywell WEBs JACE 600 as a minimum, and may not be re-used.

D. All existing JCI FA-UNT, FA-VAV, DX9100 equipment controllers (N2 devices) shall be replaced with only Honeywell LonWorks or Smart Controls LonWorks protocol controllers to match the owner's existing Tridum BAS. No existing JCI controllers are to remain.

E. All temperature, humidity, and miscellaneous sensors shall be removed and replaced with new. Existing devices shall not be re-used.

F. All terminal units actuators shall be removed and replaced with new. Existing terminal unit actuators shall not be re-used.

G. Replace all communications, controller, and sensor wiring as needed to assure a sound and comprehensive installation. Any additional wire, conduit, fittings, etc. required to mee the functional intent of the specifications shall be provided without additional cost to the Owner.

H. All labor, material, equipment, and software not specifically referred to herein must be field verified, as required, to meet the functional intent of the specifications, and shall be provided without additional cost to the Owner.

I. All demolished direct digital control components, controllers, or supervisory panels shall be turned over to the owner to assist in verification of compliance with the specification.

J. Controls Contractor is responsible for providing the proper electrical power required for all panels and equipment for a complete and operable system.

1.3 SYSTEM DESCRIPTION

A. The entire Building Automation System (BAS) shall be comprised of a network of interoperable, stand-alone digital controllers communicating via LonMark/LonTalk communication protocol to Network Area Controllers (NAC) which will communicate BACnet TCP / IP or OBIX TCP / IP to the owner's supervisory BAS server software.

B. The Building Automation System (BAS) shall be based on a framework that provides an open automation infrastructure that integrates diverse systems and devices (regardless of manufacturer, communication standard or software) into a unified platform that can be easily managed in real time over the Internet using a standard Web browser. Systems not developed on an open TCP/IP server framework platform are unacceptable.

C. All replaced data points, trends, histories, and schedules will conform to the Graphical Operator and NAC portions of this specification providing the owner a seamless system of control and navigation between new and their existing BAS.

D. A new "Home Page" graphic will be included to allow the owner to navigate to all connected points, new and existing, by on-screen hyperlink to any one of the owner's connected facilities with the use of a single user name and password.

1.4 RELATED SECTIONS

A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of these Specifications and shall be used in conjunction with this Section as a part of the Contract Documents. Consult them for further instructions pertaining to this work. The Contractor is bound by the provisions of other Divisions.

B. Refer to other Division 23 Sections for related work.

1.5 DESCRIPTION

A. General: The control system shall be as indicated on the drawings and described in the specifications.

B. Direct Digital Control (DDC) technology shall be used to provide the functions necessary for control of mechanical systems on this project.

C. Communication between the control panels and all work-stations shall be over a high speed network. All nodes on this network shall be peers. The operator shall not have to know the panel identifier or location to view or control an object. Application Specific Controllers shall be constantly scanned by the network controllers to update point information and alarm information.

D. The documentation is schematic in nature. The Contractor shall provide hardware and software necessary to implement the functions and sequences shown and operate the systems in a safe and stable manner.

1.6 QUALITY ASSURANCE

A. System Installer Qualifications

1. The Installer shall be a Certified Tridium Controls Contractor.
2. The Installer shall have an established working relationship with the Control System Manufacturer of not less than three years.
3. The Installer shall have successfully completed Control System Manufacturer's classes on the control system and have a minimum of five years experience in the design and installation of control systems. The Installer shall present for review the certification of completed training, including the hours of instruction and course outlines upon request.
4. The installer shall have an office within 100 miles of the project site and provide 24 hour response in the event of a customer call.

B. Codes and Standards: Meet requirements of all applicable standards and codes, except when more detailed or stringent requirements are indicated by the Contract Documents, including requirements of this Section.

1. Underwriters Laboratories: Products shall be UL-916-PAZX listed.
2. National Electrical Code -- NFPA 70.
3. Federal Communications Commission -- Part J.
4. ASHRAE/ANSI 135-1995 (BACnet).

C. All products used in this installation shall be new, currently under manufacture, and shall be applied in similar installations for a minimum of 2 years. This installation shall not be used as a test site for any new products unless explicitly approved by the Owner's representative in writing prior to bid date. Spare parts shall be available for at least 5 years after completion of this contract.

D. The manufacturer of the BAS digital controllers shall provide documentation supporting compliance with ISO-9001 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing). Product literature provided by the BAS digital controller manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar.

E. Only bidders having a minimum of five “Niagara AX Certified” Engineers that have successfully completed an accredited Niagara AC certification training course shall be considered qualified. Copies of actual certificates may be requested and must be supplied within 24 hours of the request.

F. The use of “Pool” or “Remote” Engineers is not acceptable. The Niagara AX Certified Engineers shall be under direct employ of the bidder and working from the installing location. Programming Engineers and Technicians not living within 100 mile radius of the installing location will be considered Pool or Remote Engineers and are not acceptable.

G. The use of “third party” Niagara “for hire” subcontractors for any programming, commissioning, setup or graphic creation, not in the direct employ of the bidding contractor shall not be permitted.

H. The successful bidder shall maintain a fully staffed office, complete with a spare parts inventory within a 100 mile radius of the customer. The distance shall adequately meet the on-site service needs of the customer and will not impact the future service cost to this Owner.

1.7 SYSTEM PERFORMANCE

A. Performance Standards. The system shall conform to the following:

1. Graphic Display. The system shall display a graphic with a minimum of 20 dynamic points. All current data shall be displayed within 20 seconds of the request.
2. Graphic Refresh. The system shall update all dynamic points with current data within 30 seconds.
3. Object Command. The maximum time between the command of a binary object by the operator and the reaction by the device shall be 10 seconds. Analog objects shall start to adjust within 10 seconds.
4. Object Scan. All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work-station will be current, within the prior 60 seconds.
5. Alarm Response Time. The maximum time from when an object goes into alarm to when it is annunciated at the work-station shall not exceed 45 seconds.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
7. Performance. Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every 5 seconds. The controller shall scan

and update the process value and output generated by this calculation at this same frequency.

8. Multiple Alarm Annunciation. All work-stations on the network shall receive alarms within 5 seconds of each other.
9. Reporting Accuracy. Table 1 lists minimum acceptable reporting accuracies for all values reported by the specified system.

a. Table 1 -- Reporting Accuracy

Measured Variable	Reported Accuracy
Space temperature	±0.5°C (±1°F)
Ducted air	±1.0°C (±2°F)
Outside air	±1.0°C (±2°F)
Water temperature	±0.5°C (±1°F)
Delta-T	±0.15°C (±0.25°F)
Relative humidity	±5% RH
Water flow	±5% of full scale
Air flow (terminal)	±10% of reading *Note 1
Air flow (measuring stations)	±5% of reading
Air pressure (ducts)	±25 Pa (±0.1 "W.G.)
Air pressure (space)	±3 Pa (±0.01 "W.G.)
Water pressure	±2% of full scale *Note 2
Electrical Power	5% of reading *Note 3
Carbon Monoxide (CO)	± 50 PPM
Carbon Dioxide (CO2)	± 50 PPM

Note 1: (10%-100% of scale) (cannot read accurately below 10%)
Note 2: for both absolute and differential pressure
Note 3: * not including utility supplied meters

1.8 SUBMITTALS

A. Contractor shall provide shop drawings and manufacturers' standard specification data sheets on all hardware and software to be provided. No work may begin on any segment of this project until submittals have been reviewed by the Engineer and Owner for conformity with the plan and specifications. A minimum of six (6) copies or a pdf copy are required. All shop drawings and a complete set of as-builts shall be done on AutoCAD, and provided to the Owner on a CD.

B. Quantities of items submitted shall be reviewed by the Engineer and Owner. Such review shall not relieve the contractor from furnishing quantities and specified functionality required for completion.

C. Provide the Engineer and Owner, any additional information or data which is deemed necessary to determine compliance with these specifications or which is deemed valuable in documenting the system to be installed.

D. Submit the following within 60 days of contract award:

1. A complete bill of materials of equipment to be used indicating quantity, manufacturer and model number.

2. Provide manufacturers cut sheets for major system components. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawings shall clearly reference the specification and/or drawing that the submittal is being submitted to cover. Include:

    a. Building Controllers
    b. Custom Application Controllers
    c. Application Specific Controllers
    d. Operator Interface Computer
    e. Auxiliary Control Devices
    f. Proposed control system riser diagram showing system configuration, device locations, addresses, and cabling.
    g. Detailed termination drawings showing all required field and factory terminations. Terminal numbers shall be clearly labeled.
    h. Points list showing all system objects and the proposed English language object names.
    i. Sequence of operations for each system under control. This sequence shall be specific for the use of the Control System being provided for this project.
    j. Color prints of proposed graphics with a list of points for display.

E. Project Record Documents: Upon completion of installation submit three (3) copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and include:

1. Project Record Drawings - These shall be as-built versions of the submittal shop drawings. One set of magnetic media including CAD .DWG or .DXF drawing files shall also be provided.
2. Testing and Commissioning Reports and Checklists.
3. Operating and Maintenance (O & M) Manual - These shall be as-built versions of the submittal product data. In addition to that required for the submittals, the O & M manual shall include:

    a. Names, address and 24-hour telephone numbers of Contractors installing equipment, and the control systems and service representative of each.
    b. Operators Manual with procedures of operating the control systems including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.
    c. Programming Manual with a description of the programming language including syntax, statement descriptions including algorithms and calculations used, point database creation and modification, program creation and modification, and use of the editor.
    d. Engineering, Installation and Maintenance Manuals that explains how to design and install new points, panels, and other hardware; preventative maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.
    e. A listing and documentation of all custom software created using the programming language including the point database. One set of magnetic media containing files of the software and database shall also be provided
    f. One set of magnetic media containing files of all color-graphic screens created for the project.

g. A list of recommended spare parts with part numbers and supplier.
h. Complete original issue documentation, installation and maintenance information for all third party hardware provided including computer equipment and sensors.
i. Complete original issue diskettes for all software provided including operating systems, programming language, operator work-station software, and graphics software.
j. Licenses, Guarantee, and Warrantee documents for all equipment and systems.
k. Recommended preventive maintenance procedures for all system components including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

F. Training Manuals: The Contractor shall provide a course outline and training manuals for all training classes at least six weeks prior to the first class. The Owner reserves the right to modify any or all of the training course outline and training materials. Review and approval by Owner and Engineer and shall be completed at least 3 weeks prior to first class.

1.9 WARRANTY

A. Warrant all work as follows:

1. Labor & materials for control system specified shall be warranted free from defects for a period of twelve (12) months after final completion acceptance by the Owner. Control System failures during the warranty period shall be adjusted, repaired, or replaced at no charge or reduction in service to the Owner. The Contractor shall respond to the Owner's request for warranty service within 24 hours during customary business hours.
2. At the end of the final start-up/testing, if equipment and systems are operating satisfactorily to the Owner and Engineer, the Owner shall sign certificates certifying that the control system's operation has been tested and accepted in accordance with the terms of this specification. The date of Owner's acceptance shall be the start of warranty.
3. Operator work-station software, project specific software, graphics, database, and firmware updates shall be provided to the Owner at no charge during the warranty period. Written authorization by Owner must, however, be granted prior to the installation of such changes.

1.10 OWNERSHIP OF PROPRIETARY MATERIAL

A. All project developed hardware and software shall become the property of the Owner. These include but are not limited to:

1. Project graphic images,
2. Record drawings,
3. Project database,
4. Job-specific application programming code,
5. All documentation.

B. Software licensing for the NAC and server software shall give the Owner the capability to control their system and determine which contractors can bid and engineer their system.

C. It shall be possible to insure the Owner can prevent unauthorized partners from accessing the system for engineering changes.

D. Software licensing shall have the freedom to individually manage authorized parties and independent parties.

E. The software licensing shall have no restrictions on which brand of NAC, server software or System Programming tools can interact with the system. Station Compatibility must = ALL and Tool Compatibility must = ALL.

F. The Owner shall accept the manufacturer's standard software and firmware licensing agreements as a condition of this contract. Such license shall grand use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

1.11 ADDED POINT AND MEMORY CAPACITY

A. The BAS software/firmware provided shall have the capacity for an unlimited number of NACs. Systems requiring future upgrades to accomplish this are not acceptable; capacity shall be provided at the time of bid.

B. Total system capacity shall have the capacity for an unlimited number of future points. Systems requiring future upgrades to accomplish this are not acceptable; capacity shall be provided at the time of bid.

1.12 TESTING AND BALANCING

A. Control Contractor shall be responsible for adjusting and readjusting the control systems as required to obtain the desired control sequencing and intent of the specifications.

B. If proper sequencing or system functions cannot be achieved with the controls, as installed, and additional controls are required, the required additional controls shall be added at the expense of the Control Contractor.

1.13 COMMISSIONING

A. Control contractor shall be responsible to work with the Commissioning Authority to verify the control system operation and Sequence of Operation for the controlled equipment, and provide appropriate documentation that the systems have been verified.

B. If any deficiencies are found in either the control system or the documentation of the system operation, the deficient controls or documents shall be repaired or replaced at the expense of the Control Contractor.

C. If the proper sequencing or system functions cannot be achieved with the controls, as installed, and additional controls are required, the required controls shall be added at the expense of the Control Contractor.

D. Control Contractor shall provide two weeks of time after the project is completed and system has been programmed and verified by Contractor to be working properly to work with the Commissioning Authority in verifying the controls system operation and sequence of operations. During those two weeks the controls contractor shall adjust and rewrite programs as required to optimize the performance of the building as deemed necessary by the Commissioning Authority. Control Contractor shall provide another 40 hours worth of site work time to alter any controls work over then next 12 months of operation from the completion date for any issues that may arise.

E. If system is not operating properly and per sequence of operation at the start of commissioning, commissioning will be put on hold until the controls are complete.

F. Control Contractor shall hire the Commissioning Authority, voluntary alternates will not be accepted. The Commissioning Authority shall be:

Craig Trierweiler, P.E. LEED AP, CxA
Matrix Consulting Engineers, Inc.
1601 E. Grand River Avenue
Lansing, MI 48906
Phone: (517) 487-2511
Email: ctrierweiler@matrixceinc.com

1.14 ON-LINE SERVICE

A. The contractor shall provide as part of their proposal, on-line service assistance for a period of one year after system acceptance, at no additional cost to the owner, to include:
1. Programming changes or modifications, including changes and adjustments to control algorithiums.
2. Graphic changes or modifications as requested by the owner or consulting engineer.
3. Operator assistance to include shor (1 hour or less) refresh training on system diagnostics and operation, i.e., system optimizations, scheduling, trending, or operator setup.
4. Consulting engineer assistance to include assistance on control system optimization.

1.15 DELIVERY, STORAGE, AND HANDLING

A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage. Storage equipment and materials inside and protected from weather.

PART 2 - PRODUCTS

2.1 SECTION INCLUDES

A. Acceptable Manufacturers.

2.2 ACCEPTABLE MANUFACTURERS

A. Base Bid: Tridium.

2.3 GENERAL

A. The Building Automation System (BAS) shall be comprised of a network of interoperable stand-alone digital controllers, Network Area Controllers, server software server, Graphical User Interface, Web Browser Clients, printers, network devices and other devices as specified herein.

B. The installed system shall provide secure password access to all features, functions and data contained in the overall BAS.

2.4 BUILDING CONTROLLERS

A. General. Provide Building Controllers to provide the performance specified in section 1 of this division.

2.5 INPUT/OUTPUT INTERFACE

A. Hard-wired inputs and outputs may tie into the system through Building, Custom, or Application Specific Controllers.

B. All input points and output points shall be protected such that shorting of the point to itself, another point, or ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24V of any duration, such that contact with this voltage will cause no damage to the controller.

C. Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of at least 12 ma to be compatible with commonly available control devices.

D. Pulse accumulation input points. This type of point shall conform to all the requirements of Binary Input points, and also accept up to 2 pulses per second for pulse accumulation, and shall be protected against effects of contact bounce and noise.

E. Analog inputs shall allow the monitoring of low voltage (0-10 Vdc), current (4-20 ma), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with, and field configurable to commonly available sensing devices.

F. Binary outputs shall provide for on/off operation, or a pulsed low voltage signal for pulse width modulation control. Binary outputs on custom and building controllers shall have 3-position (on/off/auto) override switches and status lights. Outputs shall be selectable for either normally open or normally closed operation.

G. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0-10 Vdc or a 4-20 ma signal as required to provide proper control of the output device. Analog outputs on building or custom programmable controllers shall have

status lights and a 2-position (auto/manual) switch and manually adjustable potentiometer for manual override.

2.6 AUXILIARY CONTROL DEVICES

A. Motorized dampers, unless otherwise specified elsewhere, shall be as follows:

1. Damper frames shall be 16 gauge galvanized sheet metal or 1/8" extruded aluminum with reinforced corner bracing.
2. Damper blades shall not exceed 8" in width or 48" in length. Blades are to be suitable for medium velocity performance (2,000 fpm). Blades shall be not less than 16 gauge.
3. Damper shaft bearings shall be as recommended by manufacturer for application.
4. All blade edges and top and bottom of the frame shall be provided with compressible seals. Side seals shall be compressible stainless steel. The blade seals shall provide for a maximum leakage rate of 10 CFM per square foot at 2.5" w.c. differential pressure.
5. All leakage testing and pressure ratings will be based on AMCA Publication 500.
6. Individual damper sections shall not be larger than 48" x 60". Provide a minimum of one damper actuator per section.

B. Control dampers shall be parallel or opposed blade type as indicated in the sequence of operation.

C. Electronic damper/valve actuators.

1. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator.
2. Where shown, for power-failure/safety applications, an internal mechanical, spring return mechanism shall be built into the actuator housing.
3. All rotary spring return actuators shall be capable of both clockwise or counter clockwise spring return operation. Linear actuators shall spring return to the retracted position.
4. Proportional actuators shall accept a 0-10 VDC or 0-20 ma control signal and provide a 2-10 VDC or 4-20 ma operating range.
5. All 24 VAC/DC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 W for DC applications. Actuators operating on 120 VAC or 230 VAC shall not required more than 11 VA.
6. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.
7. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation
8. Actuators shall be provided with a conduit fitting and a minimum 1m electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
9. Actuators shall be Underwriters Laboratories Standard 873 listed.
10. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque.

D. Control Valves

1. Control valves shall be two-way or three-way type for two-position or modulating service as scheduled or shown.
2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:

    a. Water Valves:

        1) Two-way: 150% of total system (pump) head.
        2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

    b. Steam Valves: 150% of operating (inlet) pressure.

3. Water Valves:

    a. Body and trim style and materials shall be per manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.
    b. Sizing Criteria:

        1) Two-position service: Line size.
        2) Two-way modulating service: Pressure drop shall be equal to the greater of twice the pressure drop through heat exchanger (load) or 50% of the pressure difference between supply and return mains but not greater than 5 psi unless noted otherwise.
        3) Three-way Modulating Service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 4 psi maximum.
        4) Valves 1/2" through 2" shall be bronze body or cast brass ANSI Class 250, spring loaded, Teflon packing, quick opening for two-position service. Two-way valves to have replaceable composition disc, or stainless steel ball.
        5) 2-1/2" valves and larger shall be cast iron ANSI Class 125 with guided plug and Teflon packing.

    c. Water valves shall fail normally open or closed as indicated in the sequence of operation as follows:

        1) Heating coils in air handlers - normally open.
        2) Chilled water control valves - normally closed.
        3) Other applications - as scheduled or as required by sequence of operation.

    d. Zone valves shall be sized to meet the control application and they shall maintain their last position in the event of a power failure.

4. Steam Valves:

    a. Body and trim materials shall be per manufacturer's recommendations for design conditions and service. Linear ports for modulating service.
    b. Sizing Criteria:

        1) Two-position service: pressure drop 10% to 20% of inlet psig.

2) Modulating service 15 psig or less: pressure drop 80% of inlet psig.
3) Modulating service 16 to 50 psig: pressure drop 50% of inlet psig.
4) Modulating service over 50 psig: pressure drop as scheduled on plans.

E. Temperature Sensors

1. Temperature sensors shall be Resistance Temperature Device (RTD) or Thermistor.
2. Duct sensors shall be rigid or averaging as shown. Averaging sensors shall be a minimum of 5 feet in length.
3. Immersion sensors shall be provided with a separable stainless steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.
4. Space sensors shall be equipped with override switch and communication port. Provide adjustable feature and display where indicated in the sequence of operation.
5. Provide matched temperature sensors for differential temperature measurement. Differential accuracy shall be within 0.2 F.

F. Humidity Sensors

1. Duct and room sensors shall have a sensing range of 20% to 80% with accuracy of ±5% RH
2. Duct sensors shall be provided with a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 20% to 95% RH. It shall be suitable for ambient conditions of -40 F to 170 F.
4. Humidity sensor's drift shall not exceed 1% of full scale per year.

G. Static Pressure Sensors

1. Sensor shall have linear output signal. Zero and span shall be field-adjustable.
2. Sensor sensing elements shall withstand continuous operating conditions plus or minus 50% greater than calibrated span without damage.
3. Water pressure sensor shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Sensor shall be complete with 4-20 ma output, required mounting brackets, and block and bleed valves. Mount in location accessible for service.
4. Water differential pressure sensor shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Over-range limit (DP) and maximum static pressure shall be 3,000 psi. Transmitter shall be complete with 4-20 ma output, required mounting brackets, and five-valve manifold. Mount in a location accessible for service.

H. Low Limit Thermostats

1. Safety low limit thermostats shall be vapor pressure type with an element 20 ft. minimum length. Element shall respond to the lowest temperature sensed by any one foot section.
2. Low limit shall be manual reset only.

I. Indoor Air Quality Sensors

1. Indoor air quality sensors shall measure both total percentage VOCs and CO2 in PPM. Sensors shall be duct or space mounted.

J. Flow Switches

1. Flow-proving switches shall be either paddle or differential pressure type.
2. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 Type enclosure, with scale range and differential suitable for intended application, or as specified.
3. Current sensing relays may be used for flow sensing or terminal devices.

K. Relays

1. Control relays shall be UL listed plug-in type with dust cover. Contact rating, configuration, and coil voltage suitable for application.
2. Time delay relays shall be UL listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable plus or minus 200% (minimum) from set-point shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA 1 Type enclosure when not installed in local control panel.

L. Transformers and Power Supplies

1. Control transformers shall be UL listed, Class 2 current-limiting type, or shall be furnished with over-current protection in both primary and secondary circuits for Class 2 service.
2. Unit output shall match the required output current and voltage requirements. Current output shall allow for a 50% safety factor. Output ripple shall be 3.0 mV maximum Peak-to-Peak. Regulation shall be 0.10% line and load combined, with 50 microsecond response time for 50% load changes. Unit shall have built-in over-voltage protection.
3. Unit shall operate between 0 C and 50 C.
4. Unit shall be UL recognized.

M. Current Switches

1. Current-operated switches shall be self-powered, solid state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system.

N. Local Control Panels

1. All indoor control cabinets shall be fully enclosed NEMA 1 Type construction with hinged door, key-lock latch, removable sub-panels. A single key shall be common to all field panels and sub-panels.
2. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600-volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide on/off power switch with over-current protection and main air gauge for control power sources to each local panel.

PART 3 - EXECUTION

3.1 EXAMINATION

A. The project plans shall be thoroughly examined for control device and equipment locations, and any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.

B. The contractor shall inspect the site to verify that equipment is installable as shown, and any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.

3.2 GENERAL WORKMANSHIP

A. Install equipment, piping, wiring/conduit parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install all equipment in readily accessible location as defined by chapter 1 article 100 part A of the NEC. Control panels shall be attached to structural walls unless mounted in equipment enclosure specifically designed for that purpose. Panels shall be mounted to allow for unobstructed access for service.

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.3 WIRING

A. All control and interlock wiring shall comply with the national and local electrical codes and Division 26 of these specifications. Where the requirements of this section differ with those in Division 26, the requirements of this section shall take precedence.

B. Install all Class 2 wires in conduit in the following locations:

1. Mechanical spaces.
2. Concealed inaccessible walls, chassis, ceiling, etc.

C. Where Class 2 wires are in concealed and accessible locations including ceiling return air plenums, approved cables not in raceway may be used provided that:

1. Circuits meet NEC Class 2 (current-limited) requirements. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.)
2. All cables shall be UL listed for application, i.e. cables used in ceiling plenums shall be UL listed specifically for that purpose.

D. Do not install Class 2 wiring in conduit containing Class 1 wiring. Boxes and panels containing high voltage may not be used for low voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

E. Where class 2 wiring is run exposed, wiring shall be run parallel along a surface or perpendicular to it, and bundled, using approved wire ties at no greater than 10 ft intervals. Such bundled cable shall be fastened to the structure, using specified fasteners, at 5 ft intervals or more often to achieve a neat and workmanlike result.

F. All wire-to-device connections shall be made at a terminal blocks or terminal strip. All wire-to-wire connections shall be at a terminal block, or with a crimped connector. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

G. Maximum allowable voltage for control wiring shall be 120V. If only higher voltages are available, the Control System Contractor shall provide step down transformers.

H. All wiring shall be installed as continuous lengths, where possible. Any required splices shall be made only within an approved junction box or other approved protective device.

I. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations in accordance with other sections of this specification and local codes.

J. Size of conduit and size and type of wire shall be the design responsibility of the Control System Contractor, in keeping with the manufacturer's recommendation and NEC.

K. Control and status relays are to be located in designated enclosures only. These relays may also be located within packaged equipment control panel enclosures. These relays shall not be located within Class 1 starter enclosures.

L. Follow manufacturer's installation recommendations for all communication and network cabling. Network or communication cabling shall be run separately from other wiring.

M. Adhere to Division 26 requirements for installation of raceway.

N. This Contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with termination’s identified at the job site.

O. Flexible metal conduits and liquid-tight, flexible metal conduits shall not exceed 3' in length and shall be supported at each end. Flexible metal conduit less than 1/2" electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal conduits shall be used.

3.4 FIBER OPTIC CABLE SYSTEM

A. All cabling shall be installed in a neat and workmanlike manner. Minimum cable and unjacketed fibber bend radii as specified by cable manufacturer shall be maintained.

B. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post installation residual cable tension shall be within cable manufacture's specifications.

C. Fiber optic cabinets, hardware, and cable entering the cabinet shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii as specified by cable manufacturer shall be maintained.

3.5 INSTALLATION OF SENSORS

A. Install sensors in accordance with the manufacturer's recommendations.

B. Mount sensors rigidly and adequate for the environment within which the sensor operates.

C. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.

D. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor readings.

E. Install duct static pressure tap with tube end facing directly down-stream of air flow.

F. Sensors used in mixing plenums, and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.

G. All pipe mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat conducting fluid in thermal wells.

H. Wiring for space sensors shall be concealed in building walls. EMT conduit is acceptable within mechanical and service rooms.

I. Install outdoor air temperature sensors on north wall complete with sun shield at designated location.

3.6 FLOW SWITCH INSTALLATION

A. Install using a thread-o-let in steel pipe. In copper pipe use C x C x F Tee, no pipe extensions or substitutions allowed.

B. Mount a minimum of 5 pipe diameters up stream and 5 pipe diameters downstream or 2 feet which ever is greater, from fittings and other obstructions.

C. Install in accordance with manufacturers instructions.

D. Assure correct flow direction and alignment.

E. Mount in horizontal piping - flow switch on top of the pipe.

3.7 ACTUATORS

A. Mount and link control damper actuators per manufacturer's instructions.

B. To compress seals when spring return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.

C. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

D. Valves - Actuators shall be mounted on valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following manufacturer's recommendations.

3.8 WARNING LABELS

A. Affix plastic labels on each starter and equipment automatically controlled through the Control System. Label shall indicate the following:

> C A U T I O N
> This equipment is operating under automatic control and may start at any time without warning.

3.9 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 2" of termination with a cable identifier and other descriptive information.

B. Permanently label or code each point of field terminal strips to show the instrument or item served.

C. Identify control panels with minimum 1 cm letters on laminated plastic nameplates.

D. Identify all other control components with permanent labels. Identifiers shall match record documents. All plug-in components shall be labeled such that removal of the component does not remove the label.

3.10 CONTROLLERS

A. Provide a separate Controller for each major piece of HVAC equipment. Points used for control loop reset such as outside air or space temperature are exempt from this requirement.

B. Building Controllers and Custom Application Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type found at each location. If input points are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used.

C. Future use of spare capacity shall require providing the field device, field wiring, point database definition, and custom software. No additional Controller boards or point modules shall be required to implement use of these spare points.

3.11 PROGRAMMING

A. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25% of available memory free for future use.

B. Point Naming: System point names shall be modular in design, allowing easy operator interface without the use of a written point index.

C. Software Programming

1. Provide programming for the system as per specifications and adhere to the strategy algorithms provided. All other system programming necessary for the operation of the system but not specified in this document shall also be provided by the Control System Contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequence of operations.

D. Graphical User Interface (GUI)

1. The graphical component of the BAS is critical importance and should consider the following descriptions and graphic representations to be the minimum acceptable. Enhanced graphics shall include detailed 2-dimensional building site and floor plan graphics, 3-dimensional equipment graphics with fan, damper and valve animations providing operators and aid to comprehending complex system operation. Every graphic page shall contain a tabular and cascading menu navigational structure, established in an HTML frame based format to allow immediate “one-click” access to other building systems without the need to back up through the navigational tree.
2. Navigation is done through the used of and HTML-based menu bar. The contents of the menu bar shall be customized to match the specific requirements of each building, while retaining the same general categories for consistency and familiarity.

    a. The menu bar shall employ cascading menus. With this navigational concept, the operator shall not be more than two mouse button operations from any view.
    b. Displays shall provide real-time information with visual display of alarm condition by change of color and/or flashing text/color background.
    c. Displays can be viewed from a non-proprietary, commercial Web Browser.
    d. Points that have been defined as data-writes, either as a digital (on/off) or analog (change value) point type will be set up such that an operator, by right-clicking, the data object or graphic, will be able to command a digital value, or modify an analog value. Operators shall view equipment status from the menu. Menu items shall include heading for major equipment categories such as Air Handling Units, Boilers, Chillers, Zone Control, Lighting, etc. Cascading menus from each major category shall allow the operator to select a particular piece of equipment; i.e. AHU-1 or Chiller.
    e. A maximum of 40 points will be provided in a single status display screen. Points that have been defined as data-writes, either as a digital (on/off) or analog (change

value) point type shall be set up such that an operator, by right-clicking the data object or graphic, shall be able to command a digital value, or modify an analog value.

E. Custom Graphics

1. Home Page Banner

a. Content

1) Customer logo
2) Current weather and time
3) Critical points (outside air temperature, hot water supply temperature, etc.)
4) Navigation icons (home, trending, alarms, schedules, reports)
5) Integrated system icons (HVAC, lighting, power monitoring, fire alarms, etc.)
6) Equipment and floor plans tabs and sub-tabs
7) Imbedded floor plan key

b. Functionality and Navigation

1) Navigate to the home page as well as access trending, alarms, schedules and reports
2) Access HVAC and other integrated systems (if applicable); view critical data points as well as trends for each point.

2. Home Page

a. The building site overview shall provide a “mouse over” function to highlight the floor plan area to be accessed as a navigational aid. Room numbers and/or names will be included at the Owner’s request. Critical date points, i.e. Outdoor Air Temperature, Outdoor Air Relative Humidity, Geothermal Loop Temperature, or National Weather Service data will be continuously visible, in real time, within the HTML frame on all screens. Additional points may be added or deleted at the Owner’s request without cost.

b. Variations to be included

1) Map view – used for multiple buildings over a large area or region
2) Campus view – used to multiple buildings in a small area
3) Building/elevation view – used for a single building with multiple floors
4) Floor plan view – used for a single building with one floor

c. Content to be included

1) Location of buildings relative to country, state or city
2) Location of buildings relative to a campus or small area
3) A floor-by-floor view of a single building
4) Location of individual equipment on a single floor

d. Functionality and Navigation to be included

1) Full banner functionality
2) Navigate to individual buildings or individual floors or areas within a single building

3. Floor Plans

a. Detailed floor plans shall be created with a vector drawing program accurately depicting the actual building layout to include all rooms, walls, and hallways. All space sensors shall be accurately placed in their actual locations and tagged with their real time space temperature and equipment each is associated with, i.e. 72.5ºF/RTU-1, 74.2ºF/MAU-1, 73.4ºF/HP-1. Floor plans too large to be practically shown with data points will provide a "mouse over" function to highlight the floor plan area to be accessed. Room numbers and/or names will be included at the Owner's request.

b. Variations to be included

1) Multiple floor view
2) Full floor view
3) Area/zone view
4) Roof view

c. Content

1) Floor plans created in a vector drawing program by either converting a DWG file or by tracing a scanned drawing
2) Accurate room labeling (room numbers and/or names)
3) Locations of temperature sensors
4) Space temperatures of each temperature sensor

d. Functionality and Navigation

1) Full banner functionality
2) Access individual equipment associated with each sensor (temperature, humidity, CO_2, etc.
3) View trending for space temperature, space humidity, CO_2 level, etc.
4) Navigate to other floors or areas within a building

4. Mechanical Systems
a. Detailed graphics for each mechanical system will include: AHUs, VAV Terminal Units, Fan-Powered Terminal Units, Chillers, Boilers, Pumps, MAU, Computer Room Air Conditioners, and EFs as a minimum. Mechanical systems will include on-screen access to their respective set-points, trend logs and schedule. All time schedules will be setup as directed by the Owner prior to final job turnover.
b. Dynamic trends of all data points shall be set up (specification will be followed as to actual number of trend points possible) prior to final job turnover. Each trend will be available directly on screen for quick trend access.
c. Data points will be shown for all relevant inputs and outputs and be positioned near the actual device. Analog and digital parameters will be able to be modified directly from the equipment screen.

5. Equipment Pages – The equipment herein may encompass some or all of the mechanical equipment specified on this project. The functions described herein are to be provided as a minimum.

   a. Boiler/Hot Water Systems

      1) Full banner functionality
      2) View 3D graphic of equipment controlled, including piping, valves, sensors and other relevant equipment to the system controlled
      3) View animated 3D graphics of all pumps
      4) Ability to sequence boilers and pumps, or send signal to sequence equipment to Boiler Control Panel (by boiler manufacturer)
      5) Ability to schedule all equipment individually
      6) Access VFD data for pumps
      7) Monitor alarms and data points (temperatures, commands and statuses) and view trends
      8) Ability to change setpoints and override equipment
      9) Ability to trend all physical system points

   b. Chiller Water/Cooling Systems

      1) Full banner functionality
      2) View 3D graphic of equipment controlled, including piping, valves, sensors and other relevant equipment to the system controlled
      3) View animated 3D graphic of all pumps
      4) Ability to sequence chillers and pumps
      5) Ability to schedule all equipment individually
      6) Access VFD data for pumps
      7) Monitor alarms and data points (temperatures, commands and statuses) and view trends
      8) Ability to change setpoints and override equipment
      9) Ability to trend all physical system points

   c. Air Handling Units

      1) Full banner functionality
      2) View 3D graphic of equipment controlled, including ductwork and piping, valves, sensors and other relevant equipment to the system controlled
      3) View animated 3D graphic of al fans and dampers
      4) Ability to schedule all equipment individually
      5) Access VFD data for fans
      6) Monitor alarms and data points (temperatures, commands and statuses) and view trends
      7) Ability to change setpoints and override equipment
      8) Ability to trend all physical system points

   d. Energy Recovery Units

      1) Full banner functionality
      2) View 3D graphic of equipment controlled, including ductwork and piping, valves, sensors and other relevant equipment to the system controlled

3) View animated 3D graphic of all fans and dampers
4) Ability to schedule all equipment individually
5) Access to VFD data for fans
6) Monitor alarms and data points (temperatures, commands and statuses) and view trends
7) Ability to change setpoints and override equipment
8) Ability to trend all physical system points

e. Makeup Air Units

1) Full banner functionality
2) View 3D graphics of equipment controlled, including ductwork and piping, valves, sensors and other relevant equipment to the system controlled
3) View animated 3D graphic of all fans and dampers
4) Ability to schedule all equipment individually
5) Monitor alarms and data points (temperatures, commands and statuses) and view trends
6) Ability to change setpoints and override equipment
7) Ability to trend all physical system points

f. Terminal Units

1) Full banner functionality
2) View 3D graphic of equipment controlled, including ductwork and piping, valves, sensors and other relevant equipment to the system controlled
3) View animated 3D graphic of all fans, pumps, and dampers; applicable also to fan powered VAV boxes
4) Ability to schedule all equipment individually
5) Monitor alarms and data points (temperatures, commands and statuses) and view trends
6) Ability to change setpoints and override equipment
7) Ability to trend all physical system points

6. Schedules

a. Graphical schedules shall allow the operator to adjust time of day schedules by dragging the On Event slider. An unlimited number of On/Off events shall be allowed for each schedule and schedules can be linked into a Master/Slave scheduling scheme. Schedules shall allow the user to add/edit/delete holiday and special event schedules. Schedules shall be included for each major piece of equipment.

7. Trending/Logging

a. Logs shall be provided for all points defined as required collection and archiving of their real-time values. Log data will be provided in HTML, XML, comma- and tab-separated value, and plain-text formats.
b. Setup parameters for each log include log intervals, number of collection samples, log collection times and archive times, delta logging with change value selection, etc.
c. For every log, the data shall be viewable in both tabular and chart formats.

d. Logs shall be archived to the server software daily at a user specified time of day. Archive data shall be available from the creation time of the log until the last archive time.
e. For every log, the data can be viewed in both tabular and chart formats.
f. Logs and archives will be accessible from a Web Browser (Internet Explorer 5.0 or greater).
g. Analog Logs: Value collected every 15 minutes for a log total of 2 days.

F. Demonstration: A complete demonstration and readout of the capabilities of the monitoring and control system shall be performed. The contractor shall dedicate a minimum of 4 hours on-site with the Owner and his representatives for a complete functional demonstration of all the system requirements. This demonstration constitutes a joint acceptance inspection, and permits acceptance of the delivered system for on-line operation.

G. Adjustments: Provide up to 4 additional site visits during the first year of operation to adjust systems and provide owner instruction as required for seasonal adjustments.

3.12 CLEANING

A. This contractor shall clean up all debris resulting from his or her activities daily. The contractor shall remove all cartons, containers, crates, etc. under his control as soon as their contents have been removed. Waste shall be collected and placed in a location designated by the Construction Manager or General Contractor.

B. At the completion of work in any area, the Contractor shall clean all of his/her work, equipment, etc., making it free from dust, dirt and debris, etc.

C. At the completion of work, all equipment furnished under this Section shall be checked for paint damage, and any factory finished paint that has been damaged shall be repaired to match the adjacent areas. Any metal cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.13 PROTECTION

A. The Contractor shall protect all work and material from damage by his/her work or workers, and shall be liable for all damage thus caused.

B. The Contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The Contractor shall protect his/her work against theft or damage, and shall carefully store material and equipment received on site that is not immediately installed. The Contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.14 TRAINING

A. Provide a minimum of 1 training session, 8 hours, throughout the contract period for personnel designated by the Owner. Computer based training may be substituted for up to 8 hours of hands on training.

B. Train the designated staff of Owner's representative and Owner to enable them to proficiently operate the system; create, modify and delete programming; add, remove and modify physical points for the system; add additional panels when required.

C. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

3.15 FIELD QUALITY CONTROL

A. All work, materials and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this Section.

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship. All visible piping and or wiring runs shall be installed parallel to building lines and properly supported.

C. Contractor shall arrange for field inspections by local and/or state authorities having jurisdiction over the work.

3.16 ACCEPTANCE

A. The control systems will not be accepted as meeting the requirements of Completion until all tests described in this specification have been performed to the satisfaction of both the Engineer and Owner. Any tests that cannot be performed due to circumstances beyond the control of the Contractor may be exempt from the Completion requirements if stated as such in writing by the Owner's representative. Such tests shall then be performed as part of the warranty.

END OF SECTION 230900